EL NIÑO/SOUTHERN OSCILLATION AND RAPA NUI PREHISTORY

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The prehistory of Rapa Nui presents us with a paradox. On an extremely isolated island with limited resources and uncertain fluctuations in climate and agricultural productivity, the pre-contact population of Rapa Nui invested huge amounts of effort into monumental architecture and statuary (see Hunt and Lipo 2001). The per capita investments in such monuments likely stand as the greatest anywhere in the ancient world. These remarkable achievements are set against a backdrop of dramatic environmental change and biotic degradation. While rampant over-exploitation and human-induced degradation are viewed by most as the primary causes of change (e.g., Bahn and Flenley 1992), climate is also cited as a significant factor in cultural change for prehistoric Rapa Nui (e.g., McCall 1993). In particular, many researchers point to El Niño/Southern Oscillation (ENSO) events resulting in adequate rains (Hunter-Anderson 1998:96), uncommonly heavy precipitation (Nunn 2000:728), drought conditions (Orliac 2000:218; Orliac and Orliac 1998:132), or as having no measurable effect on weather patterns on Rapa Nui (MacIntyre 2001:92). These contradictory statements gain relevance and beg evaluation given conditions outlined in a recent model for the evolution of cultural elaboration in uncertain environments (Hunt and Lipo 2001; Madsen et al. 1999).

In this paper we explore the effects of historic El Niño/Southern Oscillation events on Rapa Nui since 1950 and consider the implications for the island's prehistory. In conjunction with the ENSO record, we analyze rainfall data from Rapa Nui to evaluate these contrasting claims for its effects on the island. Our motivation for this analysis grew from posing this question: Can long-term ENSO records from historical and paleoenvironmental data provide an adequate proxy for reconstructing climatic history on Rapa Nui? From our analysis, we find empirical support for MacIntyre's (2001) recent theoretical assessment for ENSO and climate variability on Rapa Nui.

Rapa Nui's Paleoenvironment

Pollen analysis has demonstrated that forests once covered the island (Flenley et al. 1991), but the timing and precise mechanisms of deforestation in relation to the archaeological evidence of colonization and population changes remains uncertain. Flenley (1998) provides evidence that the timing of the decline of trees, particularly the *Jubea* palm, occurs between the arrival of people (AD 400-700) and an alleged population collapse (AD 1600-1680). Flenley and others (e.g., Diamond 1995) see a direct relationship between deforestation and demise of the island's population. Butler and Flenley (2001:81) maintain that "the eventual total elimination of forest...is almost certainly the result of human impact," while climatic change had only minor consequences for the vegetation.

Others have pointed to an important role for climate in the transformation of vegetation and potentially related cultural changes. McCall (1993, 1994), Orliac (2000:218) and Orliac and Orliac (1998:132) hypothesize that extended drought conditions linked to El Niño events may have triggered landscape and societal changes. According to Orliac and Orliac (1998:132), a massive ENSO-related drought "implies a brutal and dramatic crisis: famine, high mortality and profound social disarray." Evidence for rapid global changes around AD 1300 leading to the Little Ice Age in the Pacific indicates cooler temperatures, lower sea levels, and an increase in El Niño frequency (Nunn 2000, Nunn and Britton 2001). Nunn (2000:728) sees a correlation between an increase in both El Niño frequency and precipitation around AD 1300 throughout the Pacific and hypothesizes that it was a mechanism for the permanent depletion of the agricultural resource base on Rapa Nui. A

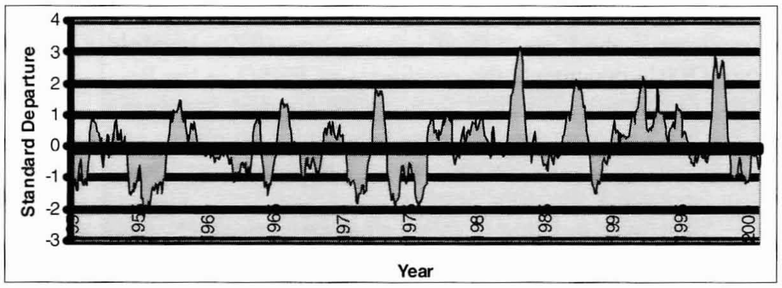

Figure 1. Multivariate ENSO Index from 1950-2000.

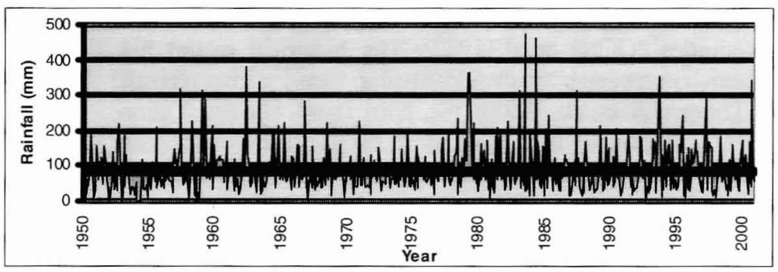

Figure 2. Monthly Rainfall from 1950-2000 showing deviations from the period's average monthly rainfall (91.38 mm).

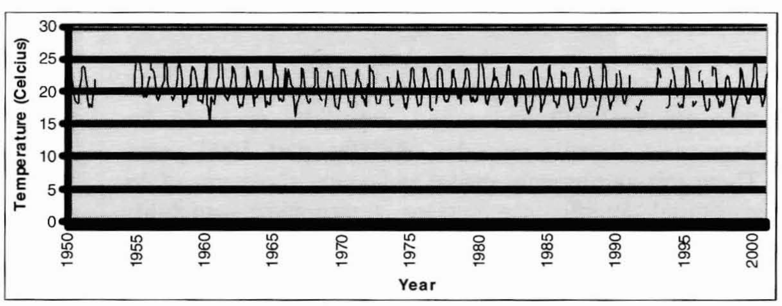

Figure 3. Average Monthly Temperature from 1950-2000.

prolonged increase in precipitation among Pacific Islands would have caused soil erosion and landslides on steep island terrain (Nunn and Britton 2001:9). Further, "rapid cooling on Easter Island could have devastated the terrestrial resource base – particularly the extensive agricultural terrace systems…" (Nunn 2000:728). Nunn suggests that resource loss resulted in competition for resources, leading to conflict as evidenced by the appearance of obsidian spearheads (*mata'a*). Abundant rainfall or drought may very well have had lasting impacts on Rapa Nui's society and may help to explain natural and cultural changes; however, we must first examine any connection between ENSO and interannual climate variability on Rapa Nui, pursuant to what scholars have hypothesized.

ENSO-related Interannual Climate Variability

Except for the annual cycle, the El Niño/Southern Oscillation is the most important coupled ocean-atmosphere phenomenon to cause global climate variability on interannual time scales. ENSO is connected with the Pacific's Walker Center, which provides an avenue for solar heat to reach the atmosphere (MacIntyre 2001). ENSO can affect global weather patterns with a variety of climatic teleconnections, with dramatic effects felt throughout the Pacific region. Increased rainfall occurs in the Galapagos, drought follows in Hawai'i, and changes in sea temperature affect marine resources in the Eastern Pacific (MacIntyre 1999). MacIntyre (2001) documents the conditions of ENSO in the Pacific Ocean. He uses data from major climatic variables from 1985 through 1992 to show the significant effects of ENSO in the Central Pacific, but he also shows that Rapa Nui lies outside that zone of effect.

If it were possible to establish a connection between ENSO history and environmental effects on Rapa Nui, it might allow us to infer climatic changes for prehistory. Researchers have used documentary historical sources to establish ENSO global teleconnections for the past two centuries (Quinn et al. 1987). The historical record has been compared with 1500-year ice core records (Thompson et al. 1992), the Nile flood history (Quinn 1992), coral growth in the eastern Pacific (Mucciarone and Dunbar 2000), and a combined multiproxy record approach (Mann et al. 2000).

Evidence suggests that the modern El Niño period was established about 5000 years ago, undergoing a change from variability on long timescales to variability on a timescale of only a few years (Markgraf and Diaz 2000:474-5). The lack of a theoretical framework for understanding the dynamics of ENSO, however, reveals the uncertainty of how ENSO varied in past centuries (Mann et al. 2000:358). The changes of ENSO teleconnections over time are not well understood, especially spanning the large-scale climatic episodes over the past 1000 years. These episodes brought spatial and temporal patterns of the equatorial Pacific sea surface temperature variability (Markgraf and Diaz 2000:479). Reconstructions of successive 50-year ENSO periods dating back to AD 1650 show constancy in the pattern of a warm eastern tropical Pacific and a cold central North Pacific – an extremely robust signature of ENSO (Mann et al. 2000:393). Integrating evidence from the Pacific and global teleconnections during the past 1000 years, it remains unclear whether the direct ENSO-induced environmental effects within the Pacific region have changed throughout Rapa Nui's prehistory.

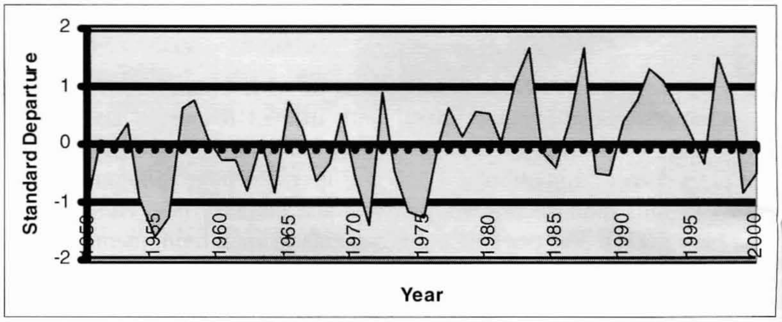

Figure 4. Average Yearly Multivariate ENSO Index from 1950-2000.

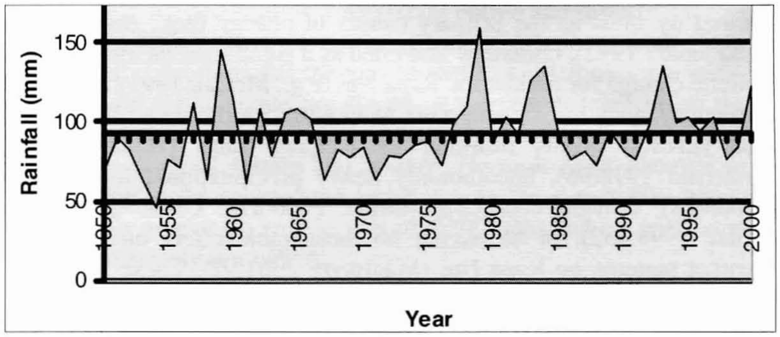

Figure 5. Average Yearly Rainfall from 1950-2000 showing deviations from the period's average yearly rainfall (91.54 mm).

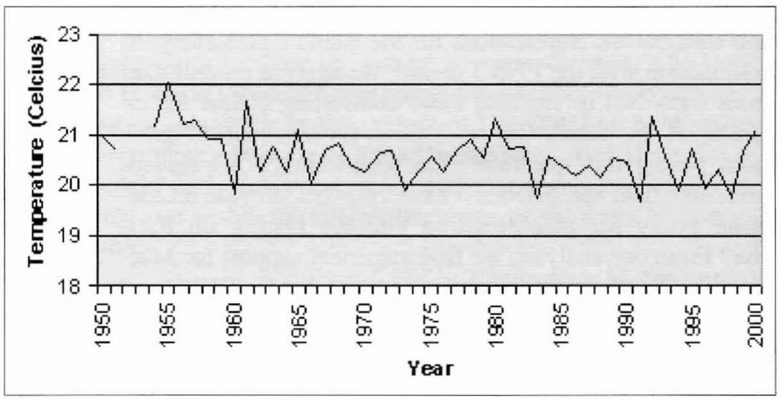

Figure 6. Average Yearly Temperature from 1950-2000.

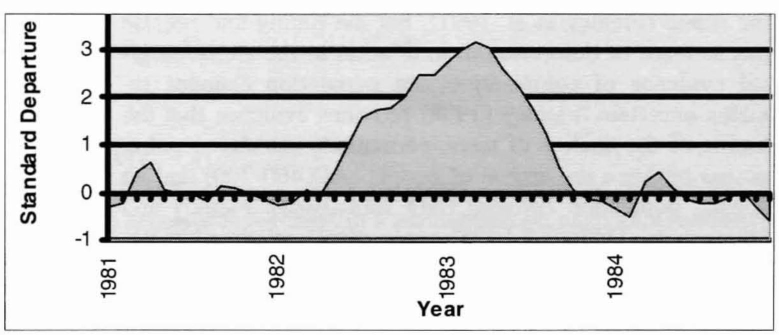

Figure 7. Multivariate ENSO Index during the 1982-83 El Niño Event.

Historic ENSO, Rainfall, and Temperature on Rapa Nui

To evaluate the effects of ENSO on Rapa Nui climatic variability and environmental uncertainty, we analyze major historic El Niño and La Niña events from 1950-2000 as a partial test for a correlation between the timing and magnitude of ENSO and patterns of rainfall and temperature. In particular, our analysis is a direct historical test of MacIntyre's model for Rapa Nui lying outside the climatic effects induced by ENSO. One index to monitor ENSO is the Multivariate ENSO Index (MEI), which is based on the six main observed variables over the tropical Pacific. These six variables are: sea-level pressure, zonal and meridian components of the surface wind, sea surface temperature, surface air temperature, and total cloudiness fraction of the sky. Positive values indicate a warm ENSO phase (El Niño) and negative values indicate a cold ENSO phase (La Niña). Bimonthly MEI data from the Pacific and monthly rainfall and monthly mean temperature data on Rapa Nui from 1950-2000 are listed in Appendices 1-3.

Figures 1-3 show bimonthly MEI, monthly rainfall, and monthly mean temperature. These data illustrate that there is no direct temporal correlation between the MEI standard departure and the amount of monthly rainfall ($r = 0.088$) or between the MEI standard departure and the monthly mean temperature ($r = -0.109$) on Rapa Nui. Figures 4-6 show the average yearly MEI, rainfall, and temperature. Again, there is no direct temporal correlation between the average yearly MEI standard departure and the amount of average yearly rainfall ($r = 0.303$) or the average yearly temperature ($r = -0.214$) on Rapa Nui.

Chu (1994) shows that there is a statistical relation between ENSO and low rainfall (drought) in Hawai'i, but that the drier conditions occur later in the year (i.e., a lag). Using the same rationale for Rapa Nui, we analyze the two largest historic El Niño events of this century (1982-83 and 1997-98) and rainfall data to test for temporal correlations (i.e., with a lag). Figures 7 and 8 highlight the 1982-83 El Niño event by comparing the MEI and monthly rainfall, respectively. Positive standard departure values range over 17 months from May 1982 until September 1983 (Figure 7). The three peaks of excessive rainfall also occur within 17 months from January 1983 until May 1984 (Figure 8). There is a weak negative correlation between the monthly MEI and monthly rainfall during these two 17 month periods ($r = -0.333$). Figures 9 and 10 highlight the 1997-98 El Niño event by similarly comparing the MEI and monthly rainfall, respectively. A comparison between the MEI from May 1997 until September 1998 (Figure 9) and the monthly rainfall from January 1998 until September 1999 (Figure 10) shows no correlation ($r = -0.051$).

To compensate for monthly variation, we average MEI data from May of the first year to September of the second year and we average monthly rainfall data from January of the second year to May of the following year. In Figure 11 we analyze the seven strongest historic El Niño events since 1950. Figure 12 shows our analysis of the seven strongest historic La Niña events since 1950. For comparison we plot

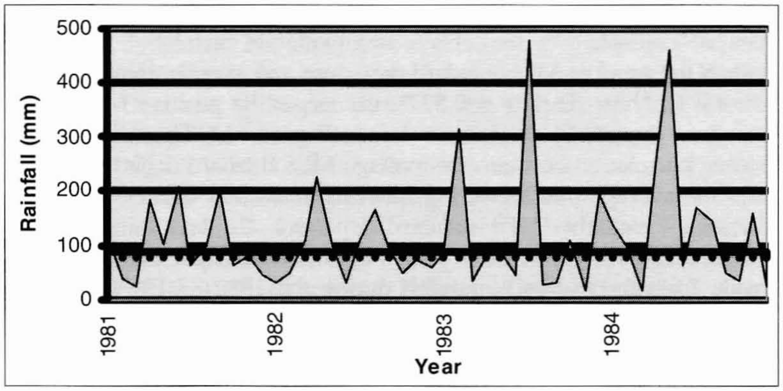

Figure 8. Monthly Rainfall during the 1982-83 El Nino Event. Monthly rainfall deviations from 1981-84 are plotted against the 1950-2000 average.

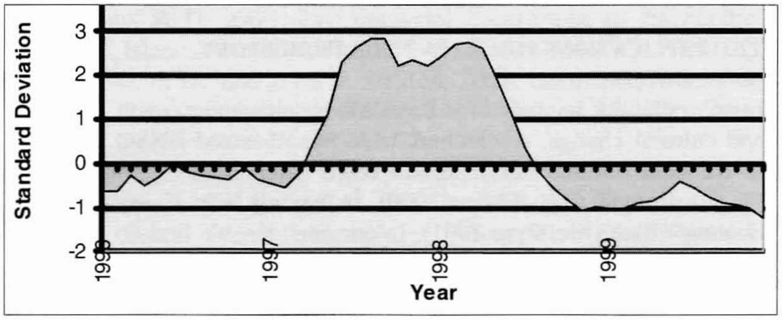

Figure 9. Multivariate ENSO Index during the 1997-98 El Niño Event.

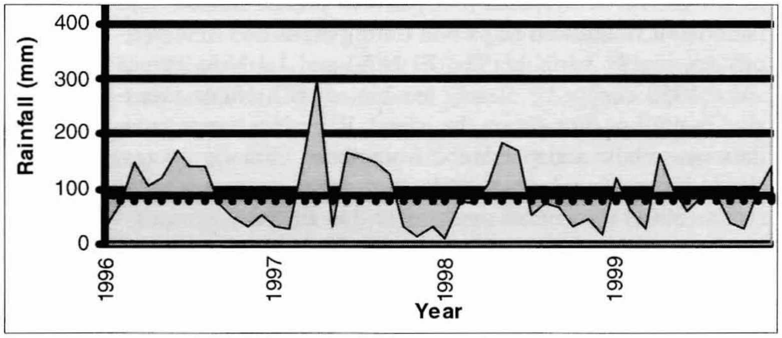

Figure 10. Monthly Rainfall during the 1997-98 El Nino Event. Monthly rainfall deviations from 1996-99 are plotted against the 1950-2000 average.

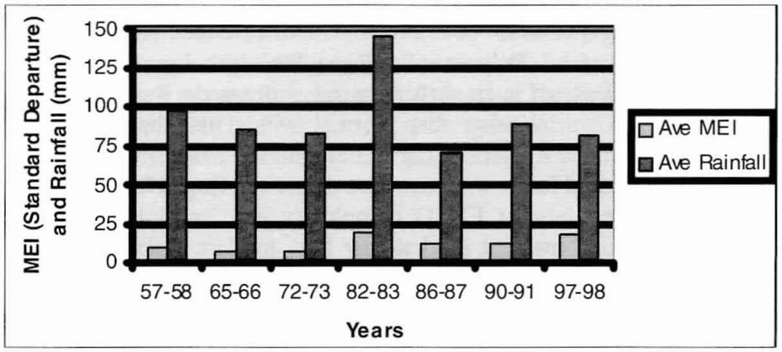

Figure 11. Average Multivariate ENSO Index and Average Rainfall during the 7 Strongest Historic El Niño Events from 1950-2000. The average MEI is from May of the first year to September of the second year (17 months); values are multiplied by 10. The average rainfall is from January of the second year to May of the following year (17 months). The y-axis uses one scale to represent both the MEI standard departure and rainfall.

the MEI and rainfall on the same graph (standard departure values are multiplied by ten). There is a moderate correlation between the average MEI standard departure and average rainfall during El Niño years (r = 0.527); the larger the positive MEI standard departure, the more rainfall (Figure 11). There is a strong correlation between the average MEI standard departure and the average rainfall during La Niña years (r = 0.891); the larger the negative MEI standard departure, the less rainfall (Figure 12). However, these trends are not significant because aside from the excessive rainfall during the 1982-83 El Niño event, the average Rapa Nui rainfall does not vary between El Niño and La Niña years. Figures 13 and 14 depict monthly rainfall during the seven strongest historic El Niño and La Niña events, respectively, since 1950. Aside from the 1982-83 event, rainfall is not distinguishable between El Niño and La Niña years, and is quite variable.

The Implications for Rapa Nui's Prehistory

In contradictory scenarios for Rapa Nui's paleoenvironment and cultural change, researchers have hypothesized ENSO as the cause of increased rainfall (e.g., Nunn 2000), prolonged drought (e.g., Orliac 2000), or having little if any climatic effect (McIntyre 2001). In our analysis, we find no clear temporal pattern among the regional Multivariate ENSO Index and historic rainfall and temperature on Rapa Nui. The two largest El Niño events of the 20th century (1982-83 and 1997-98) have comparable duration and magnitude of the MEI standard departure, yet the amount and patterns of rainfall on Rapa Nui during these two time periods are highly variable. The El Niño and La Niña events since 1950 cannot be clearly associated with either excessive rainfall or drought on the island. Rapa Nui temperature data also show independence from these climatic events. While limited in temporal scale, our results support MacIntyre's (2001) theoretical assessment that ENSO has no easily discernable climatic effect on Rapa Nui.

While we lack historical data, other environmental variables for Rapa Nui, such as sea temperature and wind, may be related to ENSO. Yet as MacIntyre (2001:92-93) notes, ENSO creates only transient displacement of equatorial water whose temperature is buffered by the Central South Pacific Ocean. The large 1982-83 El Niño event did, however, bring a reversal of trade winds that extended past western and central Polynesia to Rapa Nui (see Finney 1993). The effects of such shifting wind patterns on Rapa Nui are unknown. Weaker than normal winds may have been advantageous by decreasing the amount of evapotranspiration, a critical factor to agriculture in ancient Rapa Nui.

The uncertainty of ENSO complexity and its global effects over time make it hard to say how modern (1950-2000) conditions compare to those of prehistory. Based on our analysis of historical data, however, there is no warrant either on theoretical (McIntyre 2001) or empirical grounds (this analysis) to link specific effects from ENSO to Rapa Nui weather patterns. In short, ENSO records and their documented teleconnections are presently of no help as a proxy in reconstructing a climate history for the island, as they might indeed be elsewhere in the Pacific Islands (e.g., Hawai'i). Nonetheless, while likely independent from ENSO, the data show that rainfall on Rapa Nui is highly variable and unpredictable. This rainfall pattern, in concert with variable wind and its effects of evapotranspiration, made agricultural productivity on Rapa Nui subject to great uncertainty. Such uncertainty in critical resources in the small, isolated environment of Rapa Nui gains theoretical significance in recent models for the evolution of cultural elaboration (Hunt and Lipo 2001; Madsen et al. 1999).

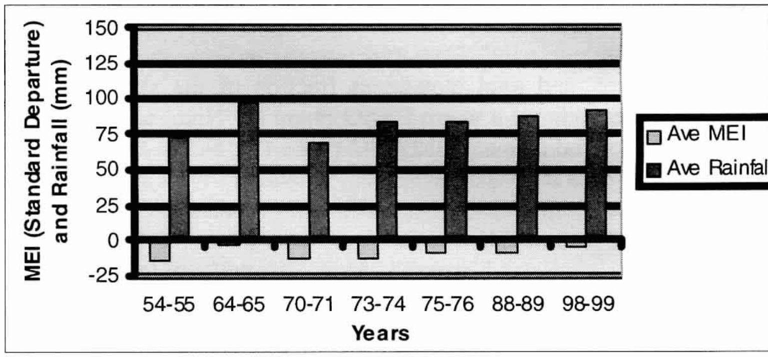

Figure 12. Average Multivariate ENSO Index and Average Rainfall during the 7 Strongest Historic La Niña Events from 1950-2000. The average MEI is from May of the first year to September of the second year (17 months); values are multiplied by 10. The average rainfall is from January of the second year to May of the following year (17 months). The y-axis uses one scale to represent both the MEI standard departure and rainfall.

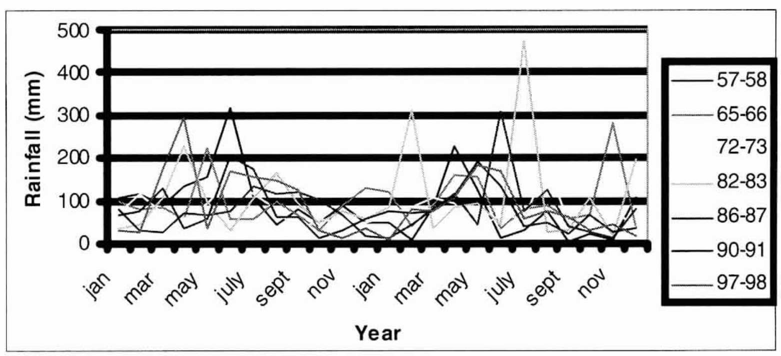

Figure 13. Rainfall during the Strongest Historic El Niño Events from 1950-2000.

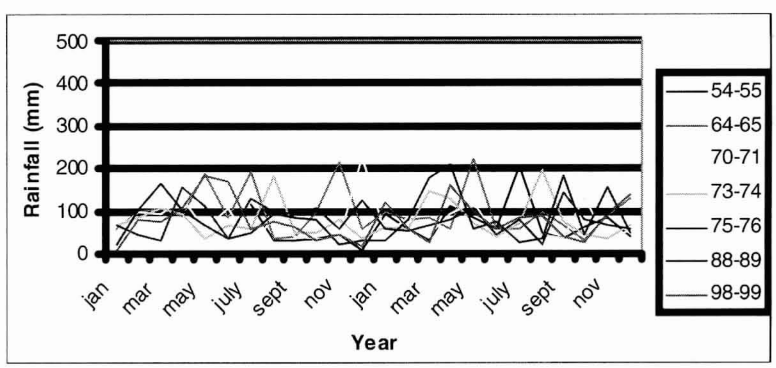

Figure 14. Rainfall during the 7 Strongest Historic La Niña Events from 1950-2000.

REFERENCES

Bahn, P. and J. Flenley. 1992. *Easter Island, Earth Island.* London: Thames and Hudson, Ltd.

Butler, K. and J. Flenley. 2001. Further Pollen Evidence from Easter Island. *Pacific 2000. Proceedings of the Fifth International Conference on Easter Island and the Pacific*, C. M. Stevenson, G. Lee, and F. J. Morin, eds. :79-86. Los Osos: Easter Island Foundation.

Chu, P. 1994. Hawai'i Rainfall Anomalies and El Niño. *American Meteorological Society* 1697-1703.

Diamond, J. 1995. Easter's End. *Discover* 9:62-69.

Finney, B. 1993. Voyaging and Isolation in Rapa Nui Prehistory. *Rapa Nui Journal* 7:1-6.

Flenley, J. R. 1998. Data and New Thoughts About Rapa Nui. *Easter Island in Pacific Context, South Seas Symposium. Proceedings of the Fourth International Conference on Easter Island and East Polynesia.* C. M. Stevenson, G. Lee, and F. J. Morin, eds. :125-128. Los Osos: Easter Island Foundation.

Flenley, J. R., A. S. M. King, J. T. Teller, M. E. Prentice, J. Jackson, and C. Chew. 1991. Late Quaternary Vegetational and Climatic History of Easter Island. *Journal of Quaternary Science* 6:85-115.

Hunt, T. L. and C. P. Lipo. 2001. Cultural Elaboration and Environmental Uncertainty in Polynesia. *Pacific 2000. Proceedings of the Fifth International Conference on Easter Island and the Pacific.* C. M. Stevenson, G. Lee, and F. J. Morin, eds. :103-115. Los Osos: Easter Island Foundation.

Hunter-Anderson, R. L. 1998. Human vs. Climatic Impacts at Rapa Nui: Did the People Really Cut Down All Those Trees? *Easter Island in Pacific Context, South Seas Symposium. Proceedings of the Fourth International Conference on Easter Island and East Polynesia*, C. M. Stevenson, G. Lee and F. J. Morin, eds. : 85-99. Los Osos: Easter Island Foundation.

MacIntyre, F. 2001. ENSO, Climate Variability, and the Rapanui, Part II. Oceanography and Rapa Nui. *Rapa Nui Journal* 15:83-94.

MacIntyre, F. 1999. Is Humanity Suicidal?' Are There Clues from Rapa Nui? *Rapa Nui Journal* 13:35-41.

Madsen, M., C. L. Lipo and M. Cannon. 1999. Fitness and Reproductive Trade-Offs in Uncertain Environments: Explaining the Evolution of Cultural Elaboration. *Journal of Anthropological Archaeology* 18:251-281.

Mann, M. E., R. S. Bradley and M. K. Hughs. 2000. Long-term Variability in the El Niño/Southern Oscillation and Associated Teleconnections. *El Niño and the Southern Oscillation, Multiscale Variability and Global and Regional Impacts.* H. F. Diaz and V. Markgraf, eds. :357-412. Cambridge: Cambridge University Press.

Markgraf, V. and H. F. Diaz. 2000. The Past ENSO Record: A Synthesis. *El Niño and the Southern Oscillation, Multiscale Variability and Global and Regional Impacts.* H. F. Diaz and V. Markgraf, eds. : 465-488. Cambridge: Cambridge University Press.

McCall, G. 1994. *Rapanui. Tradition and Survival on Easter Island.* Honolulu: University of Hawaii Press.

McCall, G. 1993. Little Ice Age: Some Speculations for Rapa Nui. *Rapa Nui Journal* 7:65-70.

McCall, G. 1976. *Reaction to Disaster: Continuity and Change in Rapanui Social Organization.* Unpublished Ph.D. thesis, The Australian National University, Canberra

Mucciarone, D. A., and R. B. Dunbar. 2000. Stable Isotope Record of El Niño Southern Oscillation Events from Easter Island, EOS. *Transactions of the American Geophysical Union* :OS51-B-06.

Nunn, P. D. 2000. Environmental Catastrophe in the Pacific Islands Around AD 1300. *Geoarchaeology* 15:715-740.

Nunn, P. D., and J. M. R. Britton. 2001. Human-Environment Relationships in the Pacific Islands around AD1300. *Environment and History* 7:3-22.

Orliac, C. 2000. The Woody Vegetation of Easter Island Between the Early 14th and the Mid-17th Centuries AD. *Easter Island Archaeology: Research on Early Rapanui Culture,* C. M. Stevenson and W. S. Ayres, eds. :211-220. Los Osos: Easter Island Foundation.

Orliac, C., and M. Orliac. 1998. The Disappearance of Easter Island's Forest: Over-Exploitation or Climatic Catastrophe? *Easter Island in Pacific Context, South Seas Symposium. Proceedings of the Fourth International Conference on Easter Island and East Polynesia.* C. M. Stevenson, G. Lee and F. J. Morin, eds. :127-132. Los Osos: Easter Island Foundation.

Quinn, W. H. 1992. A Study of Southern Oscillation-related Climatic Activity for AD 622-1900 Incorporating Nile River Flood Data. *El Niño: Historical and Paleoclimatic Aspects of the Southern Oscillation.* H. F. Diaz and V. Markgraf, eds. :119-149. Cambridge: Cambridge University Press.

Quinn, W. H., V. T. Neal and S. Antúnez de Mayolo. 1987. El Niño Occurences Over the Past Four and a Half Centuries. *Journal of Geophysical Research* 92(C13):14449-14461.

Thompson, L. G., E. Mosley-Thompson and P. A. Thompson. 1992. Reconstructing Interannual Climate Variability from Tropical and Subtropical Ice Core Records. *El Niño: Historical and Paleoclimatic Aspects of the Southern Oscillation.* H. F. Diaz and V. Markgraf, eds. :295-322. Cambridge: Cambridge University Press.

Appendix 1. Bimonthly Multivariate ENSO Index.

Year	dec/jan	jan/feb	feb/mar	mar/apr	apr/may	may/jun	jun/july	july/aug	aug/sept	sept/oct	oct/nov	nov/dec
1950	-1.036	-1.133	-1.259	-1.027	-1.399	-1.366	-1.3	-1.049	-0.621	-0.397	-1.149	-1.242
1951	-1.048	-1.182	-1.233	-0.516	-0.236	0.397	0.787	0.904	0.828	0.756	0.728	0.449
1952	0.406	0.165	0.131	0.27	-0.295	-0.666	-0.184	-0.139	0.357	0.335	-0.31	-0.1
1953	0.033	0.417	0.257	0.701	0.829	0.251	0.445	0.253	0.55	0.109	0.088	0.312
1954	-0.02	-0.045	0.075	-0.662	-1.484	-1.536	-1.403	-1.436	-1.194	-1.358	-1.095	-1.128
1955	-0.761	-0.652	-1.209	-1.644	-1.644	-2.243	-1.875	-1.975	-1.791	-1.775	-1.865	-1.873
1956	-1.429	-1.313	-1.38	-1.156	-1.349	-1.499	-1.169	-1.111	-1.34	-1.468	-1.083	-1.022
1957	-0.969	-0.41	0.09	0.388	0.891	0.753	0.987	1.125	1.162	1.104	1.112	1.18
1958	1.479	1.453	1.288	0.876	0.754	0.889	0.682	0.385	0.076	0.095	0.428	0.705
1959	0.538	0.792	0.468	0.134	0.027	-0.014	-0.209	0.071	-0.01	-0.098	-0.181	-0.255
1960	-0.285	-0.23	-0.08	-0.031	-0.351	-0.258	-0.309	-0.247	-0.508	-0.388	-0.341	-0.44
1961	-0.222	-0.236	-0.011	0.041	-0.278	-0.137	-0.26	-0.345	-0.348	-0.566	-0.393	-0.656
1962	-1.102	-1.005	-0.804	-1.059	-0.928	-0.821	-0.809	-0.557	-0.522	-0.667	-0.663	-0.511
1963	-0.756	-0.925	-0.694	-0.791	-0.416	-0.069	0.384	0.657	0.758	0.872	0.944	0.708
1964	0.854	0.498	-0.338	-0.675	-1.274	-1.124	-1.364	-1.535	-1.3	-1.194	-1.26	-0.928
1965	-0.539	-0.323	-0.231	0.109	0.54	0.945	1.436	1.522	1.444	1.222	1.379	1.269
1966	1.337	1.192	0.642	0.436	-0.146	-0.178	-0.119	0.163	-0.12	-0.049	0.026	-0.174
1967	-0.461	-0.883	-1.058	-1.057	-0.423	-0.312	-0.631	-0.512	-0.697	-0.726	-0.421	-0.385
1968	-0.654	-0.856	-0.716	-1.022	-1.072	-0.759	-0.494	-0.15	0.187	0.427	0.575	0.352
1969	0.663	0.801	0.386	0.584	0.73	0.799	0.418	0.278	0.224	0.506	0.671	0.362
1970	0.345	0.357	0.157	-0.044	-0.164	-0.682	-1.108	-1.013	-1.239	-1.099	-1.085	-1.226
1971	-1.181	-1.502	-1.775	-1.817	-1.459	-1.483	-1.238	-1.257	-1.455	-1.444	-1.39	-1.022
1972	-0.545	-0.365	-0.212	-0.149	0.544	1.118	1.816	1.759	1.58	1.628	1.719	1.761
1973	1.771	1.558	0.881	0.539	-0.129	-0.767	-1.076	-1.359	-1.699	-1.667	-1.481	-1.838
1974	-1.915	-1.792	-1.683	-1.58	-0.999	-0.654	-0.781	-0.7	-0.617	-1	-1.215	-0.884
1975	-0.507	-0.546	-0.855	-0.904	-0.867	-1.186	-1.499	-1.675	-1.813	-1.929	-1.748	-1.782
1976	-1.601	-1.354	-1.236	-1.164	-0.481	0.273	0.623	0.727	1.027	0.916	0.434	0.561
1977	0.496	0.28	0.19	0.562	0.376	0.494	0.848	0.69	0.777	0.987	0.99	0.898
1978	0.767	0.873	0.939	0.173	-0.356	-0.535	-0.368	-0.221	-0.355	-0.005	0.23	0.42
1979	0.634	0.403	0.044	0.32	0.431	0.479	0.359	0.631	0.806	0.698	0.752	1.039
1980	0.645	0.51	0.665	0.865	0.901	0.877	0.787	0.371	0.27	0.197	0.248	0.09
1981	-0.327	-0.237	0.411	0.629	0.064	-0.029	-0.046	-0.158	0.123	0.119	-0.009	-0.147
1982	-0.291	-0.212	0.063	-0.097	0.442	0.99	1.595	1.741	1.789	2.03	2.458	2.444
1983	2.734	2.984	3.174	3.044	2.581	2.235	1.793	1.24	0.529	0.065	-0.123	-0.181
1984	-0.356	-0.505	0.207	0.459	0.092	-0.13	-0.207	-0.233	-0.096	0.018	-0.307	-0.574
1985	-0.553	-0.595	-0.711	-0.464	-0.751	-0.135	-0.21	-0.429	-0.55	-0.129	-0.053	-0.278
1986	-0.312	-0.253	0.031	-0.106	0.312	0.305	0.381	0.702	1.089	1.01	0.848	1.191
1987	1.25	1.187	1.686	1.862	2.126	1.938	1.82	2.022	1.893	1.646	1.238	1.279
1988	1.12	0.69	0.497	0.337	0.063	-0.652	-1.224	-1.315	-1.527	-1.369	-1.487	-1.333
1989	-1.095	-1.189	-0.964	-0.69	-0.508	-0.319	-0.494	-0.567	-0.279	-0.355	-0.076	0.155
1990	0.217	0.56	0.866	0.407	0.551	0.432	0.078	0.082	0.405	0.312	0.355	0.346
1991	0.304	0.26	0.34	0.317	0.683	1.029	1.013	1.025	0.733	0.998	1.159	1.252
1992	1.721	1.843	2.004	2.248	2.105	1.788	1.014	0.585	0.469	0.588	0.518	0.625
1993	0.65	0.923	0.957	1.353	1.966	1.563	1.111	1.049	1.005	1.043	0.834	0.581
1994	0.382	0.189	0.126	0.427	0.609	0.612	0.796	0.586	0.653	1.327	1.222	1.168
1995	1.151	0.846	0.768	0.312	0.435	0.475	0.271	0.048	-0.355	-0.431	-0.488	-0.501
1996	-0.617	-0.639	-0.272	-0.49	-0.279	-0.018	-0.179	-0.265	-0.317	-0.382	-0.127	-0.359
1997	-0.441	-0.51	-0.178	0.444	1.094	2.304	2.623	2.863	2.84	2.205	2.333	2.208
1998	2.416	2.709	2.743	2.643	1.98	1.143	0.341	-0.176	-0.563	-0.811	-1.084	-0.955
1999	-1.014	-1.015	-0.873	-0.839	-0.664	-0.396	-0.536	-0.745	-0.881	-0.938	-1.051	-1.212
2000	-1.119	-1.129	-0.906	-0.3	-0.004	-0.279	-0.237	-0.172	-0.241	-0.34	-0.743	-0.627

Appendix 2. Monthly Rainfall (mm) from 1950 to 2000 on Rapa Nui (no data for some months).

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1950	106	35	149	22	62	42	78	191	102	10	7	27
1951	156	90	62	111	102	122	48	156	116	61	20	43
1952	5	5	40	139	32	70	27	75	163	217	134	
1953	13	190	41	130	75	106	61	21	40	33	41	15
1954	52						118	31	30	39	47	10
1955	93	55	30	113	84	57	209	50	35	64	88	42
1956	62	35	110	57	58	80	62	55	56	24	106	147
1957	107	116	92	136	159	317	105	46	78	51	91	50
1958	50	6	86	227	126	14	31	75	2	24	7	111
1959	320	150	120	113	290	70	100	70	150	230	30	100
1960	160	80	90	120	130	120	120	120	50	130	100	170
1961	30	80	90	90	80	30	120	60	40	60	20	30
1962	70	190	160	90	80	380	70	45	60	50	30	80
1963	0	70	30	100	330	140	20	37.5	80	40	40	60
1964	60	100	110	90	190	90	180	30	40	100	210	60
1965	100	80	110	60	220	60	60	100	80	80	246	100
1966	120	40	90	100	210	40	80	90	60	60	282	36
1967	57	37.5	61	93.5	36	159	54	31	82	29	50	66
1968	91	35	62.5	87	131	41	206	51.5	145	70	50	18
1969	88	70.5	64	83	78	90	161	72	88	54	16	69
1970	53	106	96	126	61	109	23	77	50	37	39	227
1971	44	83	47	95	121	41	43	44	35	131	21	59
1972	72	117	73	57	96	152	118	78	28	55	51	48
1973	68	89	110	95	34	67	60	186	48	50	81	37
1974	64	61	147	129	73.5	40	73	196	77	45	39	70
1975	68	45	30	158	113	35	127	100	93	107	62	126
1976	60	52	68	81	105	44	81	22	145	78	67	56
1977	108	86	91	145	181	43	79	84	197	66	44	67
1978	57	81	127	141	233	126	22	112	42	124	70	178
1979	124	142	117	364	364	227	80	219	59	90	50	74
1980	27	71	166	60	125	142	62	103	173	30	75	2
1981	119	40	24	184	102	210	63	100	201	64	80	46
1982	33	47	109	227	100	32	108	168	95	50	75	59
1983	84	315	36	82	93	44	475	27	32	110	18	196
1984	137	100	18	255	460	63	172	145	47	36	159	25
1985	19	48	206	35	245	82	87	29	50	124	107	49
1986	81	32	27	72	68	76	131	117	120	103	70	19
1987	16	44	78	119	45	310	75	124	43	26	17	81
1988	23.5	104	168	104	67	33	51	96	87	78	23	32
1989	31	80	177	214	61.5	77	27	36	181	45	155	50
1990	70	75	127	38	56	206	174	66	66	16	31	61
1991	74	72.5	77	112	195	135.5	41	51	22	68	28	34
1992	35	71.25	128	186	176	65	69	117	189.5	40	25	71
1993	33	70	179	114.5	166.5	152	26	182	357	194	11	132
1994	33	54	171	43	157	161.5	30	104	169	173	34	61
1995	33	42	117	161	138.5	166.25	241	14	12	130	31.5	155
1996	27	74	145.5	105	120	171	142	142	76	52	29	55
1997	30	26	174	295	33	168.625	159	149	126	31	14	33
1998	12	78	76	108	184	172	55	75	66	31	44	18
1999	120	62	28	162	98	61	85	90	40	27	95	141
2000	171	80	115	128	75	20	168	169	43	344	95	56

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Appendix 3. Average Monthly Temperature from 1950 to 2000 on Rapa Nui (no data for some months).

Year	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
1950	23.2	24.3	23.5	22.1	21	19.1	18.5	18.3	18.2	19.9	20.9	22.5
1951	23.7	24	23.8	21.9	20.7	19	17.7	18	17.7	19.7	20.5	21.8
1952												
1953												
1954							19.6	19.7	20.3	20.5	22.6	24.4
1955	25	25.2	25.2	23.5	22.2	20.5	19.2	19.3	19.1	21	22.3	
1956	24.7	23.3	23.4	23	21.4	19	19	18.7	19.3	19.9	21.2	21.6
1957	24.1	25.3	23.4	21.8	20.6		19.1	18.7	19.4	19.6	20.2	22
1958	23.3	24.5	23.7	22.1	20.2	17.7	18.6	18.2	19.9	20.9	20.9	21.1
1959	22.65	23.85	23.45	22.9	21.55	19.35	18.6	18.55	18.65	18.15	20.9	22.7
1960	23.15	24.7	17.95	17.55	15.25	19.25	18.5	18.5	17.95	20.55	21.9	22.45
1961	24.35	25.2	24.9	24.8	21.4	19.3	19.1	18.6	19.45	19.55	20.8	22.6
1962	24	23.5	22.75	20.65	19	18.8	17.4	18	17.9	19.2	20.3	21.5
1963	22.5	23.85	23.25	21.7	20.75	19.8	17.9	18.55	19.15	19.15	20.8	21.8
1964	23.2	22.75	23.15	21.4	19.75	17.5	18.4	18.1	18.1	19	20	22.1
1965	24.65	24.1	22.8	22.2	19.75	18.8	19.05	18.4	18.65	23.7	19.9	21.1
1966	21	23.35	22.45	21.3	20.7	18.6	18.9	16.15	18.15	18.7	19.55	21.7
1967	23.75	23.8	23.4	21.1	19.5	18.6	18.3	18.45	19.05		20.6	20.8
1968	23.5	23.7	23	21.5	19.5	18.9	18.6		17.9	19.2	20.6	22.7
1969	23.25	22.8	22.9	21.75	20	19.5	17.85	17.75	17.3	19.1	20.3	22.2
1970	23.35	23.35	23.3	21.6	19.95	18.5	18.35	17.8	17.5	17.5	20.4	21.8
1971	23	23.3	22.8	21.7	21.5	18.9	19.2	18	17.9	19.6	21.2	20.5
1972	24.2	23.1	23.1	22.2	20.3	19.7	18.2	18.3	18.2	19.5		
1973				22.3	21.1	19.1	18.5	17.9	18		20.6	21.7
1974	23.2	22.9	21.9	21.1	20.2	19.2	17.6	18.3	17.2	19	20.3	22.2
1975	23.4	23.5	23.4	22	20.7	19.2	17.9	18.1	18.1	18.2	20.8	21.8
1976	23.6	23.7	22.6	21.6	19.5	17.7	17	17.3		18.3	20	21.5
1977	22.9	23.6	23.6	23.2	20.1	18.8	18.4	18.6	18.4	19.1	20.5	21.1
1978	23.1	23.3	22.6	21.8	20.4	19	19.7	18.2	19.2	19.5	21.3	22.5
1979	23.3	23.6	23.2	21.2	20.2	18.5	19.1	18.5	18.4	19.2	18.7	22.6
1980	24.3	24.9	24.5	23.3	21.3	18.2	18.7	18.1	19.2	20.2	20.9	22.2
1981	23.8	23.8	21.8	22.5	21.1	19.3	18	18	18.7	19.4	20.8	21.8
1982	22.9	24.1	23.4	21.4	20.6	19.5	19.3	17.8	18.5	20	20.4	21.4
1983	22.6	22.6	22.2	20.9	19	18.2	17.1	16.8	17.9	17.8	20	22
1984	23.2	23.8	23.9	21.8	20	18.8	16.9	17.9	18.2	19.6	20.7	22.1
1985	23.8	24.2	22.8	22.2	20.8	18.4	18.4	17.5	18	18.1	19.6	20.7
1986	23.2	22.6	23	22.2	20.2	19.6	18	17.1	17.3	18.3	20	21
1987	22.7	23.8	23.2	21.7	19.2	19	17.9	17.6	17.8	18.7	20.8	22.3
1988		23.9	22.6	21.6	20	18.6		16.5	17.5	18.7	20	22.1
1989	24.3	24.2	23.2	21.8	20	18.7	17.2	18.4	18.6	18.7	20	21.3
1990	22.7		23.2	21.9	20.3	20.1	18.2	18.3	19.4	19.5	20.1	21.2
1991	22.6		23.3		20.1		17.8	17	18.1	18.6		
1992	22.8			21.7						19.8	20.6	21.9
1993	23.5	23.3	22.4	22.6		19		17.4	17.4	18.1	20.2	21.8
1994		23.8	22.6	20.8	19.3		18.2	17.4	18	17.7	20.1	21.2
1995	22.6	23.9	23.5	22.6	20.4		18.5	17.8	18.1	18.4		21.6
1996	22.9	23.1		21.7	20.1	18	17.1	17.1	17.9	19		22.6
1997	23.9	23.7	23.5	21.3	19.2	18.9	17.7	18.4	17.8	18.4	20.5	20.7
1998	21.6	22.6	22.4	20.9	18.8	17.6	16.3	17.2	18.2	19.2	20.4	22
1999	23.2	23.5	23.1	21.7	19.6	19.2	18.2	18.2	18.6	19.4	21.2	22.2
2000	23.6	25	23.7	22	20.2	19.5	19.3	17.8	18.8	19.5	21.4	22.7